AN EVALUATION OF BIOTIC INTEGRITY ASSOCIATED WITH COAL MINE RECLAMATION IN THE DRY CREEK DRAINAGE BASIN, TENNESSEE[1]

by

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Abstract: Acidification of freshwater aquatic habitats and resultant mobilization of metals due to acid rock drainage (ARD) has been documented as a principal cause of aquatic impairment throughout the eastern United States. This impairment has been documented by the scientific community through various biological community indicators. One indicator of biotic integrity within aquatic ecosystems are inhabitant benthic macroinvertebrate communities. Sequatchie Valley Coal Corporation has actively mined bituminous coal reserves and conducted reclamation in the Dry Creek drainage basin on the Cumberland Plateau of Tennessee over the last twenty years. In addition, the Dry Creek basin has historically been affected by discharges from numerous adjacent abandoned mine lands. During active operations by Sequatchie Valley Coal Corporation, benthic macroinvertebrate communities within these drainage basins have been monitored to evaluate probable hydrologic consequences of proposed mining and reclamation activities. Baseline monitoring prior to active mining and reclamation activities determined that portions of these drainage basins were already heavily impaired by acid rock drainage from abandoned mine lands, however, minimally affected, reference conditions were also present. These reference sections provided an important means for establishing best attainable conditions for biotic integrity. The utilization of passive treatment systems has been undertaken during the reclamation process to mitigate the effects of abandoned mine drainage. Biological monitoring since 1994 has illustrated the effectiveness of passive treatment methodologies, however, the reestablishment of biotic integrity within the receiving drainage basin has not been observed. Macroinvertebrate community integrity continues to be compromised by water quality impairment, and extensive physical habitat impairment from metal hydroxide precipitation and sedimentation from abandoned mine lands elsewhere in the drainage basin. As mandated by NPDES permit conditions for the reclamation of Sequatchie Valley Coal Corporation operations, evaluations of biotic integrity within the Dry Creek basin utilizing macroinvertebrate communities will continue. The macroinvertebrate data provides additional information to the scientific community on the response of biological communities to passive treatment strategies and reclamation within drainage basins affected by acid rock drainage.

Additional Key Words: biotic integrity, benthic macroinvertebrate, passive treatment system

Introduction

Aquatic ecosystems are dynamic assemblages supported by the interaction of physical, chemical, and biological features within the environment. Biota within these ecosystems exhibit specific tolerances and limitations to the various chemical and physical conditions of the environment they inhabit. When environmental conditions exceed these tolerances, biotic communities may be impaired by the combination of direct toxic exposure effects and indirect alterations of food web and physical habitat. The acidification of freshwater aquatic habitats and resultant mobilization of metals due to acid rock drainage (ARD) has been documented as a principal cause of aquatic degradation throughout the eastern United States (United States Environmental Protection Agency 1997; Pennsylvania Department of Environmental Protection 1998).

Numerous scientific studies have utilized biological communities to provide insight on degradation in watersheds which receive acid rock drainage utilizing

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biological communities (Hoehn and Sizemore 1977; Letterman and Mitsch 1978; Kimmel 1983; Rosemond et al., 1992). Biological communities are indicative of ecological integrity because they reflect the aggregate impact of water chemistry and physical habitat conditions. Benthic macroinvertebrate assemblages are widely employed as biological indicators because many individuals have limited migration patterns, reside a considerable portion of their life cycle in the aquatic environment, and have been proven to exhibit specific tolerances to various environmental stressors (United States Environmental Protection Agency 1999). Scientific researchers and resource managers have discovered that biotic integrity can be effectively evaluated utilizing a suite of macroinvertebrate community characteristics typically referenced as metrics, such as: taxa richness, composition measures, tolerance/intolerance measures, and functional feeding group dynamics (United States Environmental Protection Agency 1999). Macroinvertebrates are of value as ecological indicators because of their vulnerability to the direct and/or indirect effects of ARD.

The Sequatchie Valley Coal Corporation (SVCC) operations have mined bituminous coal reserves and conducted surface reclamation in the Dry Creek drainage basin on the Cumberland Plateau of Tennessee over approximately the last twenty years. These reclaimed coal mines discharge treated mine water into the Dry Creek drainage basin, a tributary to the Collins River. SVCC mining operations were conducted within two tributary basins (Little He Creek, Big He Creek) to Dry Creek, as well as areas draining directly to Dry Creek. Little He Creek and Big He Creek are second-order resources which produce He Creek upon their confluence. He Creek is a third-order resource which is a direct tributary to Dry Creek. Dry Creek in the vicinity of SVCC operations is a large fourth-order resource.

The Dry Creek basin has historically been impacted by the discharges from numerous adjacent abandoned mine lands. Pre-SMCRA operations extensively mined coal seams with the drainage basins of Little He Creek and Big He Creek. These pre-law operations also mined directly within the stream corridors of these two resources. Previous unreclaimed mining operations also exist throughout the Dry Creek basin and in proximity to the Dry Creek stream corridor. Water quality degradation, physical habitat alteration, and impaired macroinvertebrate communities due to effects of mine drainage were documented in the He Creek and Dry Creek basins prior to the commencement of SVCC operations (TARE Inc. 1982; Pennington 1984). Discharges from these abandoned mine lands continue to discharge untreated mine drainage into Little He Creek, Big He Creek, and Dry Creek.

SVCC has completed surface mining and reclamation within the Dry Creek drainage basin and presently conducts hydrologic monitoring. The SVCC mine reclamation objectives have been to control two distinct sources of mine water entering the basin. The first type of mine water originates from precipitation events on reclaimed surface mine areas. The second source of mine water is created from groundwater containing the byproduct of oxidized pyritic materials contacting water in the mine backfill spoil mass. The major potential sources of mine drainage to the Dry Creek basin originate from the product of the mine spoil aquifer which seeps into adjacent surface water resources. SVCC adds alkalinity, collects, oxidizes and captures metal precipitates from the mine drainage to minimize the influences on Little He Creek and Big He Creek.

SVCC has developed and implemented a passive mine water treatment and control strategy to eliminate and mitigate mine drainage discharges to the Dry Creek basin. These strategies include surface diversion of reclaimed mine areas that do not require treatment, passive treatment of impacted water, retention basins for collection of metals and sediment, and wetland areas for final polishing. The quality of discharges from these treatment facilities are regulated under the NPDES program by the Tennessee Department of Environment and Conservation for the protection of fish and aquatic life uses. The efforts of SVCC have effectively reduced concentrations of acidity and metals, and increased concentrations of alkalinity contributed to the Dry Creek drainage basin via NPDES-permitted discharges.

Methods

Sampling Site Selection

Initial research into existing macroinvertebrate community integrity within the Dry Creek basin was conducted in 1982 and 1984 (TARE, Inc. 1982; Pennington 1984). These surveys were conducted to assess the probable hydrologic consequences of further surface mining and reclamation activities in the basin by SVCC. Six biological sampling locations were established in the Dry Creek basin during 1984. These sampling locations were distributed spatially throughout the Little He Creek, Big He Creek , He Creek, and Dry Creek subdrainage basins. Biological monitoring was reinitiated by SVCC in 1994 and has continued through 2000, to assess the integrity of the Dry Creek basin during active mining and reclamation efforts. Sampling locations were reestablished throughout the various subdrainage basins associated with the mining operations, some of which were consistent with 1984 investigation.

Sampling sites throughout both efforts have been established in an effort to evaluate biotic conditions in sections of the drainage basin upstream, adjacent to, and downstream of mining and reclamation activities (Figure 1, Table 1). The upstream sites functioned as upstream control locations for evaluating biotic communities in best attainable conditions of the watershed. Control site data would provide comparisons for evaluating impacted, or recovering biotic integrity at locations subject to mining/reclamation influences.

The location of these sampling points are identified on Figure 1.

Table 1. Sampling sites utilized in the Dry Creek drainage basin

Site	Location Description
LH-1	Little He Creek upstream of mining /reclamation influences
LH-2	Little He Creek at the confluence with Big He Creek
BH-1	Big He Creek upstream of mining /reclamation influences
BH-2	Big He Creek approximately 3 kilometers upstream of the confluence with Little He Creek
BH-3	Big He Creek approximately 1 kilometer upstream of the confluence with Little He Creek
BH-4	Big He Creek at the confluence with Little He Creek
H-1	He Creek immediately downstream of the confluence of Little He Creek and Big He Creek
H-2	He Creek approximately 100 meters downstream of the confluence of Little He Creek and Big He Creek
H-3	He Creek at the confluence with Dry Creek
D-1	Dry Creek approximately 4 kilometers upstream of confluence with He Creek
D-2	Dry Creek immediately upstream of confluence with He Creek
D-3	Dry Creek immediately downstream of confluence with He Creek

Benthic Macroinvertebrate Assessments

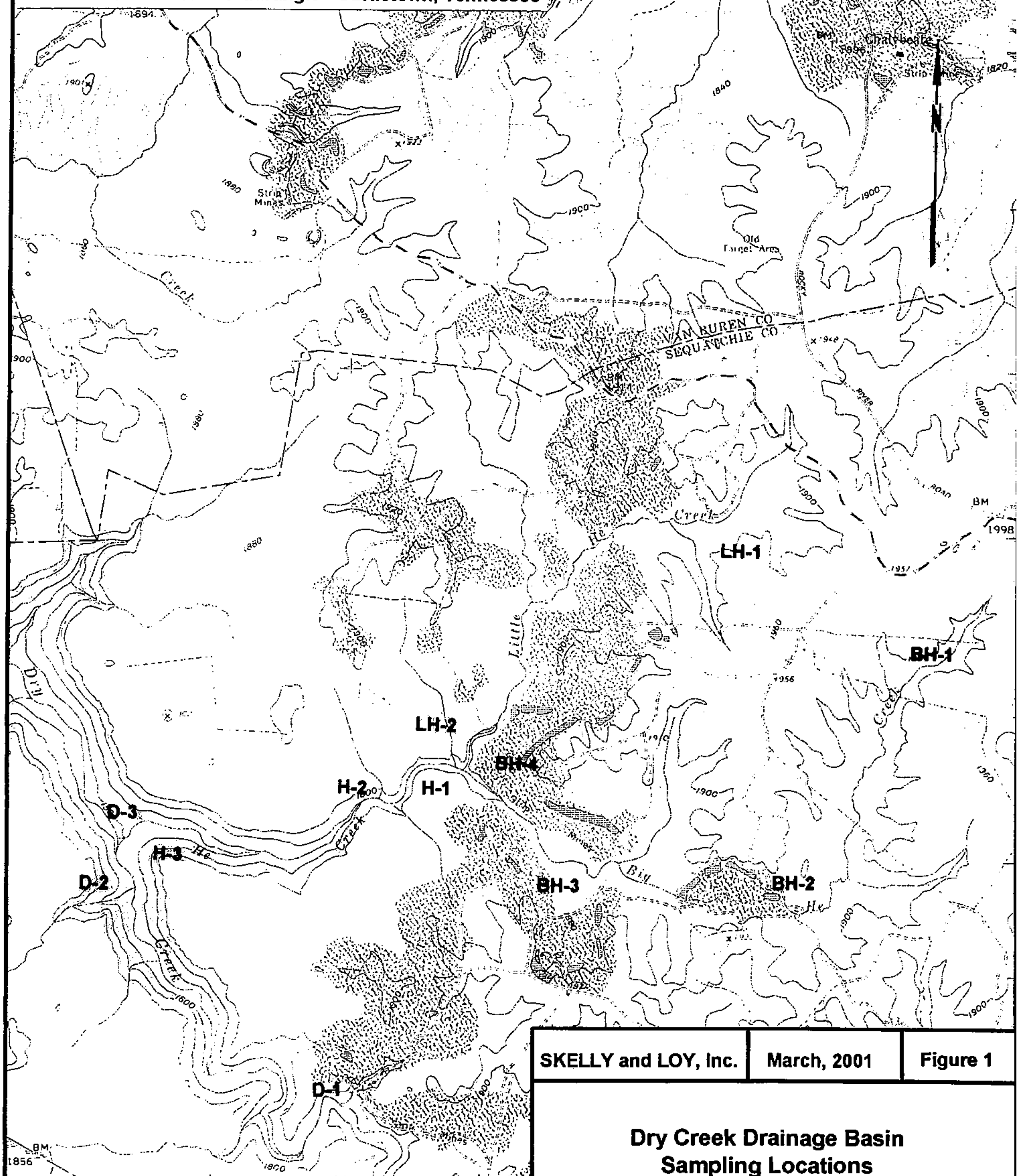
Benthic macroinvertebrate sampling during both the 1984 and post-1984 efforts were conducted utilizing qualitative methods similar to existing Rapid Bioassessment Protocols (United States Environmental Protection Agency 1989; United States Environmental Protection Agency 1999). Sampling conducted post-1984 employed a semi-quantitative approach of two composited samples per station over a two-minute sample period from riffle/run habitats. However, due to inconsistencies with sample methodologies from the 1984 effort, all biological data comparisons will be represented as qualitative sampling. All collected organisms were preserved in the field according to protocol and returned to the office for processing. All collected organisms were enumerated and identified to the lowest practical taxonomic level utilizing standard keys (Pennak 1989; Thorp and Covich 1991; Merritt and Cummins 1996). Due to inconsistencies with identification methods from the 1984 effort, all biological data comparisons were conducted at family level taxonomic identifications. Field investigations of sample points varied temporally throughout the study. Sampling dates occurred in: March 1984, June 1994, April 1998, May 1999, and June 2000.

Biotic integrity at the sampling locations was analyzed by evaluating macroinvertebrate community metrics. Metrics referenced for the analysis included measures of taxa richness, community composition, and environmental tolerance.

Table 2. Description of macroinvertebrate community metrics referenced

Community Metric	Description	Predicted response to environmental stress from mine drainage
Total Abundance	Total number of organisms contained within the sample	Decrease
Total Number of Taxa (Family Level)	Total number of family varieties within the sample	Decrease

Source: U.S.G.S. 7.5' Quadrangle - Curtistown, Tennessee



SKELLY and LOY, Inc.	March, 2001	Figure 1

Dry Creek Drainage Basin
Sampling Locations

Sequatchie County, Tennessee

Scale: 1" = 2,500'	Project No. 1600300

Modified Hilsenhoff Family Biotic Index	Hilsenhoff biotic index of pollution tolerance for families represented in sample (Hilsenhoff 1988). Family tolerance values obtained from Tennessee Biological SOP Manual (TDEC 1996)	Increase
Number of Intolerant Taxa (Family Level)	Total number of families with a tolerance value <5 as documented in Tennessee Biological SOP Manual (TDEC 1996)	Decrease
Number of EPT Taxa (Family Level)	Total number of families in the insect orders Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies)	Decrease
Percent Abundance of EPT Taxa	Percent of the total abundance of the sample composed by EPT individuals	Decrease

Physiochemical Assessments

Water chemistry and physical habitat conditions were assessed concurrently with biological sampling during the post-1984 efforts. Water chemistry evaluation included both in situ field measurements, and collection of samples for laboratory analysis. Field water quality measurements of pH, specific conductance, temperature, and dissolved oxygen were conducted with instrumentation provided by YSI Incorporated. Water samples were preserved EPA-certified laboratory for analysis. Laboratory analytes typically included total iron, total manganese, total acidity, total alkalinity, total dissolved solids, and total suspended solids. Stream discharge estimates were obtained with a Marsh-McBirney 201 Electromagnetic Flow Meter according to U.S.G.S. protocols and procedures.

A qualitative assessment of available physical aquatic habitat was conducted during the investigations of 1998-2000 according to assessment methodologies outlined by the Tennessee Department of the Environment and Conservation (TDEC 1996). Physical habitat evaluations for riffle/run prevalent streams included a characterization of in-stream cover, epifaunal substrate, embeddedness, channel alteration, sediment deposition, frequency of riffles, channel flow status, bank vegetative protection, bank stability and riparian vegetative zone.

Results

Biological and physiochemical conditions differed dramatically from upstream reference sampling locations to those points historically impacted by mined area drainage inputs. Biological integrity at Stations BH-1, BH-2, and LH-1 located upstream of surface mining and reclamation activities have consistently exhibited greater total abundance, total number of taxa, number of intolerant taxa, number of EPT taxa, and percent abundance of EPT taxa when compared with downstream stations (Table 3).

Upstream control station water quality was typically characterized by moderately acidic conditions with minimal concentrations of total iron, total manganese, and specific conductance. In comparison, stations located downstream of mined areas were minimally to extremely acidic, with elevated to extreme metals concentrations (Table 4). In general, physical habitat conditions were suboptimal to optimal throughout the entire drainage basin except for stream bed and substrate material. Sampling points downstream of mined areas were moderately to severely impaired by sedimentation and metal hydroxide precipitant which had filled interstitial areas of, and effectively cemented much of the substrate material. Available benthic habitat at the Dry Creek station D-1 may be naturally limited by bedrock outcrops which function as the stream bed material.

Recovery of the macroinvertebrate community downstream of mined areas has been minimal despite the mitigative efforts of SVCC. However two critical considerations must be acknowledged. First, while SVCC continues to effectively treat mine water associated with their operation, numerous discharges from abandoned mine lands continue to impair the subdrainage basins of Dry Creek. Biological integrity will continue to be compromised in these resources until these abandoned mine land discharges are addressed. Second, the degradation of the stream bed and substrate from abandoned mine drainage documented in these drainages prior to SVCC operations may be the most chronic detriment to the recovery potential for aquatic biota.

Table 3. Comparison of benthic macroinvertebrate community metrics
Dry creek drainage basin 1984-2000

Biological Monitoring Location	Total Abundance	Taxa Richness (Family Level)	Modified Hilsenhoff Family Biotic Index	Number of Intolerant Taxa (Family Level)	Number of EPT Taxa (Family Level)	Percent Abundance of EPT Taxa
1984 Little He Creek -1(LH-1)	61	15	5.26	8	7	27
1994 Little He Creek-1 (LH-1)	11	4	3.76	3	3	82
1998 Little He Creek-1 (LH-1)	141	16	4.02	11	11	77
1984 Little He Creek -2 (LH-2)	0	0	NA	0	0	0
1994 Little He Creek-2 (LH-2)	4	1	6.00	0	0	0
1998 Little He Creek-2 (LH-2)	2	1	0.20	1	1	100
1999 Little He Creek-2 (LH-2)	1	1	0.20	1	1	100
2000 Little He Creek-2 (LH-2)	54	1	6.00	0	0	0
1999 Big He Creek-1 (BH-1)	125	14	2.36	8	8	87
2000 Big He Creek-1 (BH-1)	249	12	4.78	6	6	47
1984 Big He Creek -2 (BH-2)	128	15	4.88	8	7	28
1994 Big He Creek-2 (BH-2)	14	4	4.86	2	1	14
1998 Big He Creek-2 (BH-2)	29	9	3.00	4	3	59
1999 Big He Creek-2 (BH-2)	47	7	4.05	4	3	32
2000 Big He Creek-2 (BH-2)	64	6	5.98	1	1	2

Table 3 (Continued)

1984 Big He Creek -3 (BH-3)	24	7	4.18	4	4	33
1998 Big He Creek-3 (BH-3)	109	9	1.82	6	6	93
1994 Big He Creek-4 (BH-4)	0	0	NA	0	0	0
1998 Big He Creek-4 (BH-4)	0	0	NA	0	0	0
1999 Big He Creek-4 (BH-4)	2	2	3.10	1	1	50
2000 Big He Creek-4 (BH-4)	10	1	6.00	0	0	0
1994 He Creek -1 (HC-1)	5	1	6.00	0	0	0
1998 He Creek -1 (HC-1)	0	0	NA	0	0	0
1999 He Creek -1 (HC-1)	0	0	NA	0	0	0
2000 He Creek -1 (HC-1)	13	1	6.00	0	0	0
1984 He Creek -2 (HC-2)	4	1	6.00	0	0	0
1994 He Creek-2 (HC-2)	2	1	6.00	0	0	0
1999 He Creek -2 (HC-2)	0	0	NA	0	0	0
2000 He Creek -2 (HC-2)	1	1	6.00	0	0	0
1998 He Creek -3 (HC-3)	4	3	6.25	0	0	0
1984 Dry Creek (D-1)	7	2	5.79	1	1	4
1994 Dry Creek (D-1)	1	1	4.90	1	0	0
1998 Dry Creek - 1 (D-1)	0	0	NA	0	0	0
1999 Dry Creek - 1 (D-1)	9	5	5.49	1	1	11

Table 3 (Continued)

2000 Dry Creek - 1 (D-1)	41	1	6.00	0	0	0
1998 Dry Creek - 2 (D-2)	15	7	3.82	5	4	53
1998 Dry Creek - 3 (D-3)	6	2	3.10	1	1	50

Table 4. Comparison of water quality conditions Dry creek drainage basin 1994-2000

Biological Monitoring Location	Field pH (S.U.)	Specific Conductance (microsiemens)	Total Iron (mg/L)	Total Manganese (mg/L)	Stream Flow Estimate (GPM)
1994 Little He Creek-1 (LH-1)	5.30	35	0.26	ND	620
1998 Little He Creek-1 (LH-1)	5.30	39	0.17	0.01	855
1994 Little He Creek-2 (LH-2)	3.20	1100	22.0	24.0	1023
1998 Little He Creek-2 (LH-2)	3.90	235	6.10	6.10	720
1999 Little He Creek-2 (LH-2)	3.33	558	0.89	9.10	680
2000 Little He Creek-2 (LH-2)	3.16	1235	10.60	30.10	405
1999 Big He Creek-1 (BH-1)	5.54	11	0.19	0.10	185
2000 Big He Creek-1 (BH-1)	5.26	14	0.68	0.10	122
1994 Big He Creek-2 (BH-2)	5.40	200	0.94	1.20	76
1998 Big He Creek-2 (BH-2)	5.70	40	0.22	0.23	1260
1999 Big He Creek-2 (BH-2)	5.58	79	0.12	0.42	216
2000 Big He Creek-2 (BH-2)	5.78	303	0.90	2.56	144

Table 4 (Continued)

1998 Big He Creek-3 (BH-3)	5.60	305	0.41	1.50	2790
1994 Big He Creek-4 (BH-4)	6.40	1400	15.0	24.0	1489
1998 Big He Creek-4 (BH-4)	5.73	440	3.50	5.30	3555
1999 Big He Creek-4 (BH-4)	6.27	811	1.02	5.30	1089
2000 Big He Creek-4 (BH-4)	6.29	1153	22.10	29.50	450
1994 He Creek -1 (HC-1)	5.40	1200	19.0	74.0	2810
1998 He Creek -1 (HC-1)	5.24	450	4.50	5.60	6885
1999 He Creek -1 (HC-1)	5.35	667	1.44	4.10	2327
2000 He Creek -1 (HC-1)	5.12	1117	26.80	39.00	1049
1994 He Creek-2 (HC-2)	6.80	1000	14.0	20.0	4109
1999 He Creek -2 (HC-2)	6.70	645	1.06	5.60	2183
2000 He Creek -2 (HC-2)	6.21	1062	17.00	28.60	1287
1998 He Creek -3 (HC-3)	5.62	360	6.10	6.70	4500
1994 Dry Creek (D-1)	2.10	205	3.00	4.30	8588
1998 Dry Creek - 1 (D-1)	5.25	130	4.20	3.60	14940
1999 Dry Creek -1 (D-1)	4.78	196	0.31	3.40	4019
2000 Dry Creek -1 (D-1)	3.72	374	3.16	10.50	5598
1998 Dry Creek -2 (D-2)	5.56	80	1.10	1.70	22950
1998 Dry Creek -3 (D-3)	5.70	230	3.60	4.30	20250

Discussion

Habitat acidification and the associated mobilization of metals attributed to acid rock drainage has impacted more than 7,500 miles of stream throughout West Virginia, Pennsylvania, Maryland, Virginia, Ohio, Tennessee, Kentucky, and Alabama (United States Environmental Protection Agency 1997). Research has suggested that exposure of mine spoil material when unremediated may lead to chronic inputs of ARD into aquatic systems for greater than 50 years (Herricks 1977; Verb and Vis 2000). The direct effect of mine drainage on aquatic ecosystems is readily identifiable by the biotoxicity of extreme acid and dissolved metal concentrations, and the smothering of available benthic habitat by metal hydroxides. Indirect effects such as the elimination of food web structure, production dynamics, and nutrient cycling also impair the aquatic ecosystem. Lotic systems which are subjected to chronic disturbance mechanisms, such as ARD, respond via the elimination or reduction of susceptible species and the evolutionary selection of resistant species and phenotypes (Yount and Niemi 1990).

The inherent ability of a lotic ecosystem to recover from these types of disturbance is determined primarily by certain physical characteristics of the system and the characteristics of the organisms in the system (Yount and Niemi 1990). Physical characteristics include factors such as flushing rates and the presence of refugia. Biological characteristics may include life histories, reproductive rates, and dispersal abilities. Another important factor is the removal, or remediation of the disturbance mechanism. In the case of ARD this includes the abatement of continued degradation and restoration of hospitable habitat conditions both in terms of water quality and physical habitat to the aquatic resource.

The Dry Creek basin has historically been, and continues to be impacted by the discharges from numerous adjacent abandoned mine lands. Pre-SMCRA operations extensively mined coal seams throughout the basin, including mining directly in the stream corridor of Little He Creek and Big He Creek. The deleterious effects of mine drainage on the biological communities of Little He Creek, Big He Creek, He Creek, and Dry Creek were evident prior to the commencement of SVCC operations. However, biological monitoring sponsored by SVCC since 1984 has provided insight to the recovery of sections of the Dry Creek drainage basin from ARD.

Little He Creek is a second-order resource which originates in undisturbed deciduous forest habitat upslope of historic and recent mining activities. Station LH-1 was established as a reference control location for comparison against LH-2 which is located at the confluence with Big He Creek. Macroinvertebrate communities at LH-1 consistently illustrated greater total abundance, taxa richness, biotic index, number of intolerant taxa, number of EPT taxa, and percent abundance of EPT taxa when compared to LH-2. The macroinvertebrate community at LH-1 was typically composed of intolerant taxa such as *Stenonema, Serratella, Ameletus, Isoperla, Pycnopsyche, Brachycentrus, Rhyacophila,* and *Hexatoma*. Little He Creek at LH-2 is still heavily impacted by the effects of ARD, particularly by high acidity and metals concentrations, and extreme physical habitat degradation by metal hydroxide precipitation in the substrate. The macroinvertebrate community at LH-1 has been typically composed of two taxa tolerant to highly acidic conditions, *Chironomiidae*, and the stonefly *Leuctra*. The stoneflies *Leuctra* and *Amphinemura* are documented to exhibit tolerances to depressed pH conditions (Sutcliffe and Hildrew 1989).

Big He Creek is a second-order resource which has similar origins to Little He Creek in undisturbed deciduous forest habitat upslope of historic and recent mining activities. Four sampling points have been evaluated throughout the subdrainage basin. Macroinvertebrate communities at BH-1, BH-2, and BH-3 consistently illustrated greater total abundance, taxa richness, biotic index, number of intolerant taxa, number of EPT taxa, and percent abundance of EPT taxa when compared to BH-4.

Intolerant taxa observed in the upper subdrainage basin of Big He Creek included *Serratella, Ameletus, Habrophleboides, Isoperla, Pycnopsyche, Psychomia, and Hexatoma.* Station BH-3 demonstrated improvement of the biological community in comparison to the 1984 sampling effort and may be related to reclamation activities in that portion of the basin associated with SVCC operations. Based upon the water quality data, these activities have created favorable pH conditions at BH-4; however, the macroinvertebrate community has shown minimal recovery.

He Creek is a third-order resource in the Dry Creek basin which originates from the combination of Little He Creek and Big He Creek. Both Little He Creek and Big He Creek have been, and continue to be impaired by the effects of ARD, especially where the two merge into He Creek. Three sampling points were evaluated throughout the He Creek subdrainage basin. Stations H-1 and H-2 were located within 100 meters of the origin, while H-3 was located at the confluence with Dry Creek. In comparison to reference sections, macroinvertebrate communities have been heavily impacted throughout the subdrainage basin. Minimal recovery may be occurring at the confluence with Dry Creek as observed by the additions of *Nigronia* and *Sialis* to the chironomid community. He Creek represents a continuation of the effects of elevated metals concentrations, and physical habitat degradation impairing Little He Creek and Big He Creek.

Dry Creek is a large fourth-order resource which has been historically impaired by abandoned mine land discharges in several headwater tributary basins. Three sampling points were evaluated along Dry Creek. Station D-1 is located on Dry Creek downstream of a portion of the drainage basin which was mined by SVCC. Stations D-2 and D-3 were located in relation to the confluence with He Creek. Although reference stations on the smaller Little He and Big He Creeks may not be appropriate for comparison with a larger drainage such as Dry Creek, macroinvertebrate communities and water chemistry conditions within Dry Creek continue to be impaired by multiple mine drainage sources. Community metrics such as total abundance, taxa richness, biotic index, number of intolerant taxa, number of EPT taxa, and percent abundance of EPT taxa portray a limited community of mine drainage tolerant individuals. Available benthic habitat at D-1 is naturally limited by bedrock outcrops as well as metal hydroxide particulate material. Trends of recovery within Dry Creek were observed approximately 4 kilometers downstream at Station D-2 prior to the contribution of He Creek. The 1998 data illustrated improvement in the macroinvertebrate community composition, and improved water quality conditions at D-2 when compared to D-1. This recovery was diminished at D-3, however, possibly due to the effects of He Creek.

Treatment efforts continue by SVCC to remediate ARD effects, however much of the Little He Creek, Big He Creek, He Creek, and Dry Creek drainage basins continue to be impacted by abandoned mine land drainage and the influences from historic mining operations within the stream corridor. This data provides insight on the effects of historic abandoned drainage in headwater tributaries such as Little He Creek and Big He Creek and their eventual influences on larger order receiving resources.

Conclusions

The response of biotic integrity to acid rock drainage typically results in the reduction of community abundance, taxa richness, and elimination of intolerant taxa, especially ephemeropterans (Roback and Richardson 1969; Armitage 1980; PA DEP 1998; Soucek et al. 2000). Macroinvertebrate community data collected between 1982 and 2000 within the Dry Creek drainage basin further validates those observations. However, considerably less research has evaluated the recovery of aquatic resources and biotic integrity once the impairment source(s) have been removed or mitigated. Recovery will not likely proceed until the complete reclamation of an aquatic resource is complete including both the contributory basin and physical habitat within the watercourse.

Reclamation activities within the Dry Creek drainage basin have been undertaken by SVCC in an effort to remove and mitigate potential sources of mine drainage impairment related to their operations. These efforts have effectively reduced concentrations of acidity and metals, and increased concentrations of alkalinity contributed to the drainage basin via NPDES-permitted discharges. However, the magnitude of abandoned mine drainage effects elsewhere on Little He Creek, Big He Creek, and Dry Creek continues to minimize the beneficial effects of SVCC treatment efforts in the Dry Creek drainage basin.

Macroinvertebrate communities downstream of mined areas continue to be comprised of limited populations of taxa tolerant to the effects of mine drainage as documented in the 1982 and 1984 sampling efforts. Minimal biological recovery has been evinced at these locations by the exclusive inhabitation by pollution tolerant taxa such as chironomids or the stonefly *Leuctra;* however, this recruitment may be considered a limited improvement in comparison to formerly depauperate conditions. Macroinvertebrate communities will be limited to taxa which can tolerate the ambient water quality conditions and inhabit the impaired substrate conditions attributed to the continued influences of historic mine drainage. Past research has indicated that longer recovery times were observed for disturbances which resulted in the alteration of physical habitat (Yount and Niemi 1990). The alteration of physical habitat by acid rock drainage is not only eliminates habitat, but also poses the risk of continued toxicity from precipitated metal hydroxide compounds (Herr and Gray 1997).

Physical characteristics including flushing rates and the presence of refugia are critical for biological recovery to occur. The presence of adequate refugia has been demonstrated in the upper basins of Little He Creek and Big He Creek; however, due to their small headwaters nature, the ability of these resources to flush the effects of stream bed and substrate degradation from abandoned mine drainage may be limited. Hence, the reestablishment of biotic integrity throughout the Dry

Creek drainage basin will continue to be impeded until the multiple sources of historic abandoned mine drainage which continue to discharge are addressed and restoration of physical aquatic habitat occurs.

As mandated by NPDES permit conditions for the reclamation of SVCC operations, evaluations of biotic integrity within the Dry Creek basin utilizing macroinvertebrate communities will continue. The macroinvertebrate data will provide additional information to the scientific community on the response of biological communities to passive treatment strategies and reclamation within drainage basins affected by acid rock drainage.

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